Appendix N -- LOXAHATCHEE RIVER PRE-DEVELOPMENT RUNOFF

CONTENTS

Purpose

The objective of this analysis was to attain two independent estimates of pre-development run-off levels from the seven basins that provide flow input to the Loxahatchee River. The seven basins are Jonathan Dickinson, Coastal, Estuary, C-18 Canal/Corbett WMA, Cypress Creek/Pal-Mar, Groves, and Wild & Scenic River/Jupiter Farms, and descriptions of these basins can be found in Chapter 2 of the document. The two methods utilized to estimate the pre-development run-off levels were Manning's Equation and simulations using the Natural System Model (NSM).

Methods

Estimates of the pre-development flow conveyence to the Loxahatchee River were obtained by modeling certain known hydraulic characteristics of the stream such as historic flow conditions, and incorporating tentative assumptions such as roughness and bottom slope. The first estimate of pre-development flow capacities for water elevation depths of 15, 16, 17, 18 and 19 NGVD were derived using Manning's Equation, which is a method commonly used to estimate the average velocity of large flows in streams, channelized waterways, and canals (Watson and Burnett, 1995). The Manning equation is $V = ((1.49)(R^{2/3})(S^{1/2})) / n$.

where
V= average fluid velocity (L/T; feet/second)
1.486 = coefficient used when the other variables are given in "American" units
R (hydraulic radius) = A/P_w
    A= cross-sectional area of flow (ft^2)
    P_w = wetted perimeter (f)
S= gradient of the stream (dimensionless)
n= Manning roughness coefficient (dimensionless)

The cross-section value used in the calculation was obtained by selecting a typical cross section from a 1940 topographical map, which is depicted in **Figure N-1**. The geometric characteristics of the selected "typical" cross section are summarized in

Table N-1.

Table N-1 Geometric Characteristics of a Typical Cross Section of the Loxahatchee River (c. 1940).

Distance from left overbank (ft)	Elevation (ft NGVD)	Length of reach (ft)
0	20	
4576	19	4576
8008	18	3432
11264	17	3256
14256	16	2992
17160	15	2904
20240	16	3080
24992	17	4752
27720	18	2728
31944	19	4224

An estimate of the bottom slope was also obtained from the 1940 topographical map by measuring the differences in contour lines.

The Manning roughness coefficient (n) is a measure of the roughness of a stream or channel bed, which effects flow velocity. It is a function of the cross section based on its vegetation, soil type, and geometry, and lower n values represent smoother cross sections. For this application the n values were considerably greater than those used in open channel flow conditions, and were chosen based on flow conditions in the ENR project, WCAs and sloughs, which are similar to pre-development conditions. Sensitivity analyses were conducted by increasing and decreasing the n values by twenty percent to determine the effect that the chosen Manning's roughness coefficient had on the overall conveyence estimates.

The calculated average flow velocities were then converted to flow using the equation Q=VA where Q= flow (cubic feet/second) V= velocity (feet/second) and A = cross-sectional area of flow in the channel (ft^2).

The Natural System Model (NSM) is a two-dimensional coupled surface/ground water model that incorporates the dominant physical processes affecting hydrology in south Florida. The model domain is discretized into grid cells, and the spatial properties required to simulate each of the hydrologic processes are estimated for each cell. The spatial properties utilized in this model included vegetation/landscape type, land surface elevation, aquifer depth and permeability, soil storage coefficients, initial water levels, and river properties such as river location and dimension, outlet specifications, and coefficients for river to overland flow and river to aquifer interaction. This model was developed to provide a better understanding of the predrained hydrology of the Everglades system in south Florida. It was used in this analysis to gain a better understanding of the natural distribution of flows to the Loxahatchee River. District HSM staff conducted descriptive statistics (mean, median, maximum, minimum, standard deviation, and 50% exceedence probability) from the average monthly data generated for the 31 year simulation period (1965 to 1995).

Results

The values used in the Manning equation calculation along with the calculated flow velocities and flow values are listed in **Table N-2**.

Table N-2 Hydraulic Parameters and Estimations for a Typical Cross Section of the Loxahatchee River (s_f = 2.27E-5 from 1940's survey)

(1) Elevation (ft NGVD)	(2) Top Width (ft)	(3) Incr. Area (ft^2)	(4) Total Area (ft^2)	(5) Incr. WP (ft)	(6) Total WP (ft)	(7) R_H (ft)	(8) Water Depth (ft)	(9) Manning n	(10) Flow velocity (ft/sec)	(11) Flow (cfs)
19	27368	23540	53108	7656	27368	1.94	4.0	0.50	0.022	1170
18	19712	16720	29568	5984	19712	1.50	3.0	0.53	0.017	518
17	13728	9856	12848	7744	13728	0.94	2.0	0.57	0.012	153
16	5984	2992	2992	5984	5984	0.50	1.0	0.60	0.007	22
15	0	0	0	0	0		0.0			

(1) Elevation (ft NGVD) taken from 1940's survey for the selected cross section.
(2) Top Width (T, measured in ft) estimated from points in Table 1 (ie. for each elevation value the location closer to left overbank was subtracted from the value measured closer to the right overbank).
(3) Incremental Areas estimated from T(2) using trapezoidal approach at one-foot elevation intervals.
(4) Total (cumulative) Area (ft^2) by adding the areas of the elevation intervals from bottom to top (from 15 to 19 ft NGVD).
(5) Incremental Wetted Perimeter (ft) is the length of the cross section between two consecutive elevations (1-foot intervals) obtained from points in Table 1.
(6) Total Wetted Perimeter (ft) is the cumulative wetted perimeter and is calculated by adding all the reaches from bottom to top (from 15 to 19 ft NGVD).
(7) Hydraulic Radius (R_H) in ft, defined in hydraulics as Area/WP.
(8) Water (normal) depth in ft, obtained from the elevations (every one foot, in this case)
(9) Manning roughness coefficient (n). The n values used in this analysis were chosen based on flow conditions in the ENR project, WCAs and sloughs, which are similar to pre-development conditions. As the water depth decreases the value of n increases by a small amount.
(10) Flow velocity (V) in ft/sec represented as an average for the considered water depth. It is obtained from Manning equation, $V = (1.486/n) * R_H^{2/3} * s_f^{1/2}$.
(11) Discharge (Q) in cfs estimated as the average flow velocity (V) multiplied by the area (A) for each selected water depth.

The calculated flow velocity values obtained in the analysis appeared to be appropriate. Elevation (NGVD) was plotted against the calculated discharge values (cfs) to generate the stage duration curve shown in **Figure N-2.** This curve can be used to estimate the discharge at various depths.

The sensitivity analysis, which was conducted to determine how the chosen n values affected the flow velocity values at various depths, is shown in **Table N-3**.

Table N-3 The Results of Increasing and Decreasing Manning's Roughness Coefficient Value by 20 Percent on the Flow Discharges of various Water Depths.

Water depth (ft)	Manning n	Discharge (cfs)	20 % increase in n	Discharge (cfs)	Percent decreased in Q	20 % decrease in n	Discharge (cfs)	Percent increased in Q
1.0	0.60	22	0.72	19	13.6	0.48	28	27.3
2.0	0.57	153	0.68	127	17.0	0.46	191	24.8
3.0	0.53	518	0.64	431	16.8	0.42	647	24.9
4.0	0.50	1170	0.60	975	16.7	0.40	1462	25.0

Assuming a uniform cross section (ie. perfectly rectangular), it is possible to estimate the change in discharge due to changes in Manning's roughness coefficient directly from the Manning equation. When n is reduced by twenty percent, the discharge increases by 25% (0.80 factor in the denominator of the equation) whereas when n is increased by twenty percent, the discharge decreases by 16.67% (1.20 factor in the denominator of the equation). The percentages of increase and decrease in flow shown on **Table N-3** are slightly different from the previously estimated changes. These differences are attributed to variations in area, wetted perimeter, and hydraulic radius, and a non-uniform cross section, especially from 15 to 16 ft MGVD where it tended to be more triangular in shape.

The descriptive statistics generated from the NSM Model are presented in **Table N-4** and the Flow-Duration Curve derived from the simulation is shown on **Figure N-3**. The results indicate that the data is skewed and not distributed normally because the mean value is more than twice as great as the median flow and the flow obtained from the Flow-Duration analysis (50 percent exceedence probability).

Table N-4 Statistical Estimates from Average Monthly Data (NSM 31-year Simulation)

Mean (cfs)	Median (cfs)	Maximum (cfs)	Minimum (cfs)	Standard Deviation (cfs)	Flow for 50 % Exceed. Probability (cfs)
229.5	113.8	1480.9	0	287.7	106.3

Discussion

Due to the absence of historical records, it was necessary to estimate the average pre-development water depth for the cross section utilized in this analysis. It was estimated that the average water depth condition for a 1-in-2 year return period ranged between 1.5 and 1.75 feet. The flow discharges, which were calculated for those depths using

Manning's equation and Q=VA, were 65 cfs and 100 cfs, respectively, as exemplified on **Table N-2**. The flows corresponding to the median flow and flow for 50% exceedence probability as predicted by the NSM model, were 113.8 cfs and 106.3 cfs, respectively.